# College of Information Science and Technology

# Designing Nutritional Programs with Case-Based Reasoning

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**Abstract.** This paper describes a system aimed at prescribing nutritional programs using Case-Based Reasoning (CBR). A nutritional program is a balanced dietetic plan aimed at better health conditions of the individuals. The nutritional task refers to prescribing a nutritional program as a therapy for a given nutritional disorder, in accordance to the patient's characteristics that act as constraints, functions and goals. The main reason to use a case-based reasoning system in designing nutritional programs lies in the nature of the nutritional expert task, which is carried out by reusing past experiences. Nutritional professionals usually express their knowledge with generalizations, even when pointing specific instances as examples. This has motivated us to model the starting case base with a prototypical memory. Our approach to perform the nutritional task in a case-based reasoning system can be viewed as a two-fold process. First, the characteristics, symptoms, goals and restrictions are used to classify the new patient in a group associated to a diagnostic category. Second, the hypothetical case corresponding to the category that classifies the new case provides the design that represents the solution to be adapted to solve the new case. The system we are describing contemplates the nutritional task from the collection of patient's characteristics performing the diagnosis task implicitly, and prescribing the nutritional program (meal plan) to treat the respective nutritional disorder.

# 1. Introduction

The nutritional task refers to prescribing a nutritional program as a therapy for a given nutritional disorder, in accordance to the patient's characteristics that act as constraints, functions and goals. In this sense, this task can be viewed as a design task. This paper describes a system aimed at prescribing nutritional programs using a Case-Based Reasoning (CBR) system.

Computerized systems to support the nutritional task have been developed and used since the sixties (Eckstein, 1967). A milestone on such research occurs with the development of case-based reasoners. The research developed by Hammond (1986) implementing CHEF is a CBR application to plan meal recipes. In this research, recipes are viewed as plans. CHEF plans through the reminding of recipes that were successful in similar situations and modifies the recipes according to the conditions of the new situation. Performing a design task, JULIA (Hinrich & Kolodner, 1991) suggests complete meals. The experiences are described according to constraints and the solutions are designs that satisfy them. However, neither systems deal with the nutritional task as a target, and this is because they are not designed to handle variables conducting to the diagnosis task. Planning recipes and designing meals are secondary tasks in the nutritional domain, in which a nutritional program is designed to solve a nutritional disorder in accordance with the patient's needs, symptoms, constraints and goals. Both CHEF and JULIA attempt to meet the user's needs concerning to their preferences but not considering nutritional needs. The system we are describing contemplates the nutritional task from the collection of patient's characteristics, performs the diagnosis task implicitly, and prescribes the nutritional program (meal plan) to solve the respective nutritional disorder. Another example of a computerized system to support the nutritional task is CAMP (Marling, 1997) that design meals from nutritional recommendations. Camp represents an attempt to support another secondary task on the nutritional domain since it requires the nutritional knowledge to be input to the system.

# 2. Nutritional Programs

The nutritional consultation consists of four steps: interview, evaluation, design of the nutritional program, and follow up (BAXTER, 1993). The nutritional program is based upon information from different natures, such as anthropometric, biochemichal, clinical trials, food intake, and psychosocial; all addressing the nutritional status of the patient (KRAUSE, 1995). The overall evaluation of these information support the nutritional diagnosis in which the nutritional program is grounded. The complementing issues in this task embody a nutrition education and intervention counseling and a follow up guided by patient's feedback.

The nutritional program is carried out through a balanced dietetic plan aimed at better health conditions of the individuals. This dietetic plan considers the food intake, nutrients, balanced amounts of foods concerning quality and quantity, food distribution, meals per day, individual requirements, preferences and food habits. The real challenge when designing the dietetic program is in including all essential nutrients in the indicated quantities (proteins, 10-10-15%; fat, 25-30%; and carbohydrates, 55-60%, of calories per day, respectively), in accordance with RDA (Recommended Dietary Allowances), (Assis, 1997). The nutritional professional has to calculate the total amount of calories per day, and the indicated amounts of salt, sugar, cholesterol, fiber and fat (specially saturated) (KRAUSE, 1995). Besides, this professional has to take into account the patient's habits or disorders to reach a fully efficient program.

# 3. Using RBC to design Nutritional Programs

The main reason to use a case-based reasoning system to design nutritional programs lies in the nature of the nutritional expert task, which is carried out by reusing past experiences. Using case-based reasoning to the nutritional task aims at benefiting from the advantage of retrieving a nutritional program design instead of building it from scratch. Every nutritional consultation is an experience and thus it can be represented as cases in the system. This provides the availability of past knowledge to support the performance of the nutritional task.

The nutritionist, from the interview, can characterize the new situation to retrieve similar ones from the case base. Hence, supporting an evaluation and providing a starting point to build the design of the nutritional program by adapting the design (or a combination of) associated to the most similar cases.

Case-based Reasoning has enlarged its fields of application to several domains and tasks such as design. The experience-based reasoning is recognized as the cognitive process in design creation. While searching for solutions, the designers can research on the existing ones and adapt previous solutions (Oxman & Voss, 1996).

The design task embodies a great amount of decisions and the level of difficulty depends upon the knowledge available, the definition of variables and the results. This is why the expert knowledge can be very helpful, since it guides these choices and analysis.

Our approach to perform the nutritional task in a case-based reasoning system can be viewed as a two-fold process. First, the characteristics, symptoms, goals and restrictions of the patient are used to assess the similarity of each case of the base as an attempt to classify the new patient in a group associated to a diagnostic category. Second, the hypothetical case (in a prototypical memory) corresponding to the category that classifies the new case provides the design that represents the solution to be adapted to solve the new case.

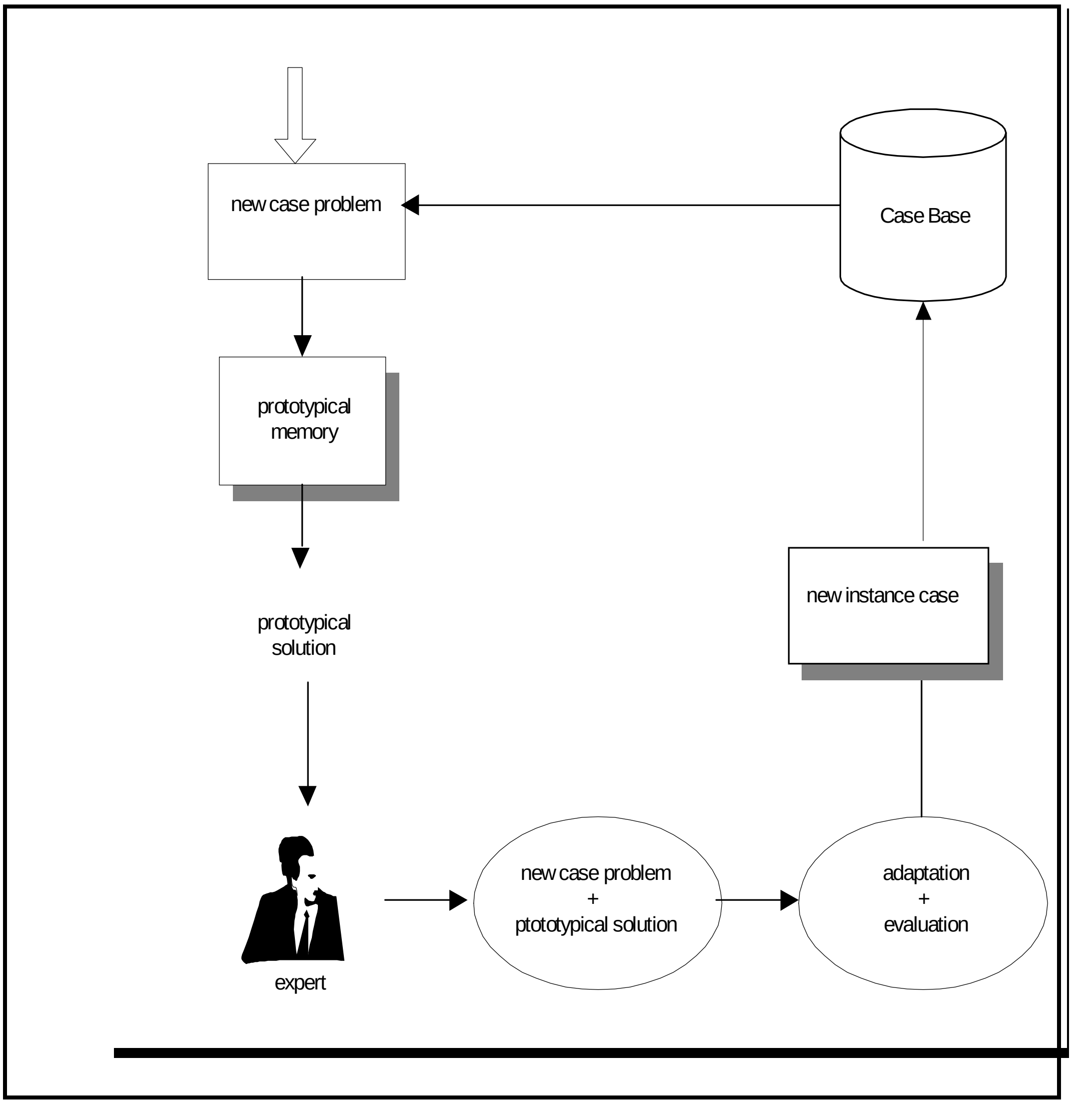


**Figure 1: System Project**

# 4. The Prototypical Memory

Expert knowledge is represented in a CBR system in the case base, in assessing similarity between cases, evaluating differences, and performing adaptation. The case base is the means to deal with domain experiences in a CBR system in which the expert knowledge is stored. The nutritionist first learns the theoretical knowledge and, through time, incorporates experiences to this knowledge turning it into expertise. However, the nutritional professionals usually express their knowledge with generalizations, even when pointing specific instances as examples. This has motivated us to consider starting our system from a prototypical memory and making use of the research provided by PROTOS (Bareiss & Slator, 1991). The use of a prototypical memory enables the implementation of a case base that comprises every important category of nutritional programs.

The prototypical memory is built concerning variations on symptoms, goals, and other relevant characteristics that cannot be adapted, representing the categories based on a knowledge acquisition from the experts. One example is a category related to obesity and an associated solution of a nutritional program aiming at weight loss. The characteristics indicate a BMI (Body Mass Idex) in the interval between 25 and 45 (kg/m$^2$), a caloric intake history in the interval (0.5, 10) representing a ratio over the caloric needs, and the presence of obesity in close relatives. The specific values of caloric intake, for instance, can be adapted thus the values to be used as indexes are the relative ones. This prototype (category) suggests a nutritional program that embeds a weight loss goal, representing a collection of experiences of the expertise employed by the nutritionists. This nutritional program is a diet prescription expressed through a meal plan (suggestions on meals and foods) contemplating alternatives and nutritional recommendations.

## 5. System Design

The overall project consists of several phases, aiming at different purposes, namely: prototyping, acquiring cases, adaptation knowledge elicitation, programming the final version.

The first phase comprises the development of the first prototype that demonstrates the feasibility of the use of the CBR paradigm to the nutritional task based on a prototypical memory.

The second phase refers to the use of this first prototype by some experts who search for actual cases to feed the system. From a new case, the user inputs all the characteristics asked by the system which returns a category most similar to this new case. The expert includes this new case to the case base.

Simoultaneous to the secong phase, a third phase is employed when the experts watch the functioning of the CBR system obserbing adaptation needs. For every new case that is added to the case base, the expert elicits the possible required knowledge that the system would need to have represented to dynamically adapt the prototypical program to prescribe it to the new case (see

Figure 1). These second and third phases have no time frame set *a priori* as they end when experts consider that the case base of actual individual instances comprises a sufficient amount of cases to be used, with reduced adaptation knowledge requirements.

The fourth phase is accomplished by programming a PROTOS-style retrieval system. At this phase, the adaptation knowledge acquired during the second phase is programmed to be performed automatically also enabling an automatic integration to the new cases (learning) after an evaluation confirmed by an expert's feedback. The final version of the system integrates the automatic adaptation phase. A new case is input and it is assessed to determine the category it classifies. The similarity assessment is then carried out only with the actual cases that are linked to the chosen category. The most similar case is selected and its nutritional program is adapted to fit this new case. This new case is solved and after a positive evaluation, it is added to the case base and linked to the originating category, enabling the system to learn with experience.

### 5.1 The First Prototype

The cases are an interpretation of the domain experiences modeled to accomplish the system's task. The nutritional experience is related to individuals who have a nutritional disorder that is classified according to symptoms and who deserve a special nutritional program in conformity with their needs, goals and adequacy. As the task has two distinctive moments, cases have to comprise differently a description of the problem and the solution. The appropriate interpretation of the experiences is indicated by domain experts who have chosen characteristics to describe the problem,: among others, sex, age, height, weight, BMI, daily and average activity level, caloric intake ratio, and the solution.

Expert knowledge also teaches us on which dimensions one can compare two nutritional experiences in order to assess their similarity. These knowledge is modeled through the selected attributes that comprise the indexing vocabulary, namely, sex, age, IBM, food intake and activity level.

## 6. Conclusions and Future Developments

One advantage provided by an intelligent system shared by CBR systems is the ability to store knowledge from several experts making the expert task it represents more reliable and less error prone. Besides, when employing the paradigm of reminding a similar previous episode, humans are subject to emotional blocks that may avoid them of retrieving a relevant solution. A computational system, as long as it fulfills theoretic requirements, guarantees that the similar experiences are retrieved.

Although our prototype requires expert knowledge to be acquired, one always benefits from the ease representation provided by CBR systems. Besides, since an efficient adaptation method can be implemented, with knowledge acquired from adaptation experiences, learning gains consistency contributing to the increasing robustness of the system.

An improvement considered necessary to our system is a proper modeling of concepts such as BMI, age, etc. The use of fuzzy sets is indicated in order to increase the precision of the membership of a given new case to a category in the case base.

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